

NESTING BIOLOGY AND FLOWER RELATIONSHIPS OF *XYLOCOPA SONORINA* SMITH IN HAWAII (HYMENOPTERA: ANTHOPHORIDAE)¹

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Carpenter bees have been the object of numerous studies during recent years (Anzenberger, 1977; Barrows, 1980; Bonelli, 1976; Gerling and Hermann, 1978; and Hurd, 1978). As a result of these and other works, much information was added to our knowledge of the biology of these bees and new insight has been gained of their biology, especially with respect to the social relationships.

During my sabbatical leave, I spent 9 months at the Department of Entomology of the University of Hawaii at Manoa and had a chance to observe the Hawaiian carpenter bee, *Xylocopa sonorina* Smith, to study some of its biological attributes, and to compare them with some of the results mentioned in other recent works. The results of these studies are reported herein.

Materials and Methods

Observations were conducted of both unmarked and marked bees. Marking was carried out by painting the thorax and/or abdomen of the bees with typewriter correcting fluid. For X-ray observations, the bees were marked with a piece of wire glued to their notum. Nests were obtained from different locations on Oahu and placed on the roof of the Entomology building of the University of Hawaii at Manoa, where they were kept in the open, under a rain-shelter. These nests were taken about twice a week to an X-ray machine and radiographed. Additional observations were conducted in natural nesting sites the most noteworthy of which was the "Fashion Fabrics" store of Kapiolani and Piikoi Ave. in Honolulu, where several hundred 2.5 × 5 cm thick redwood poles of various lengths had been used for decorative purposes. These served as nesting substrates for numerous carpenter bees (Fig. 1). The experiment station of the University of Hawaii at Waimanalo, where Dr. T. Nishida has conducted his studies in the past (Nishida, 1963), also served as a place of observations. X-ray radiograms were taken with a "Hewlett Packard" "Faxitron" at about 3 mAmp, 25-70 KVp, for 5-15 seconds and a distance of 30 cm; Kodak AA+ or Agfa Industrex films were used.

Results

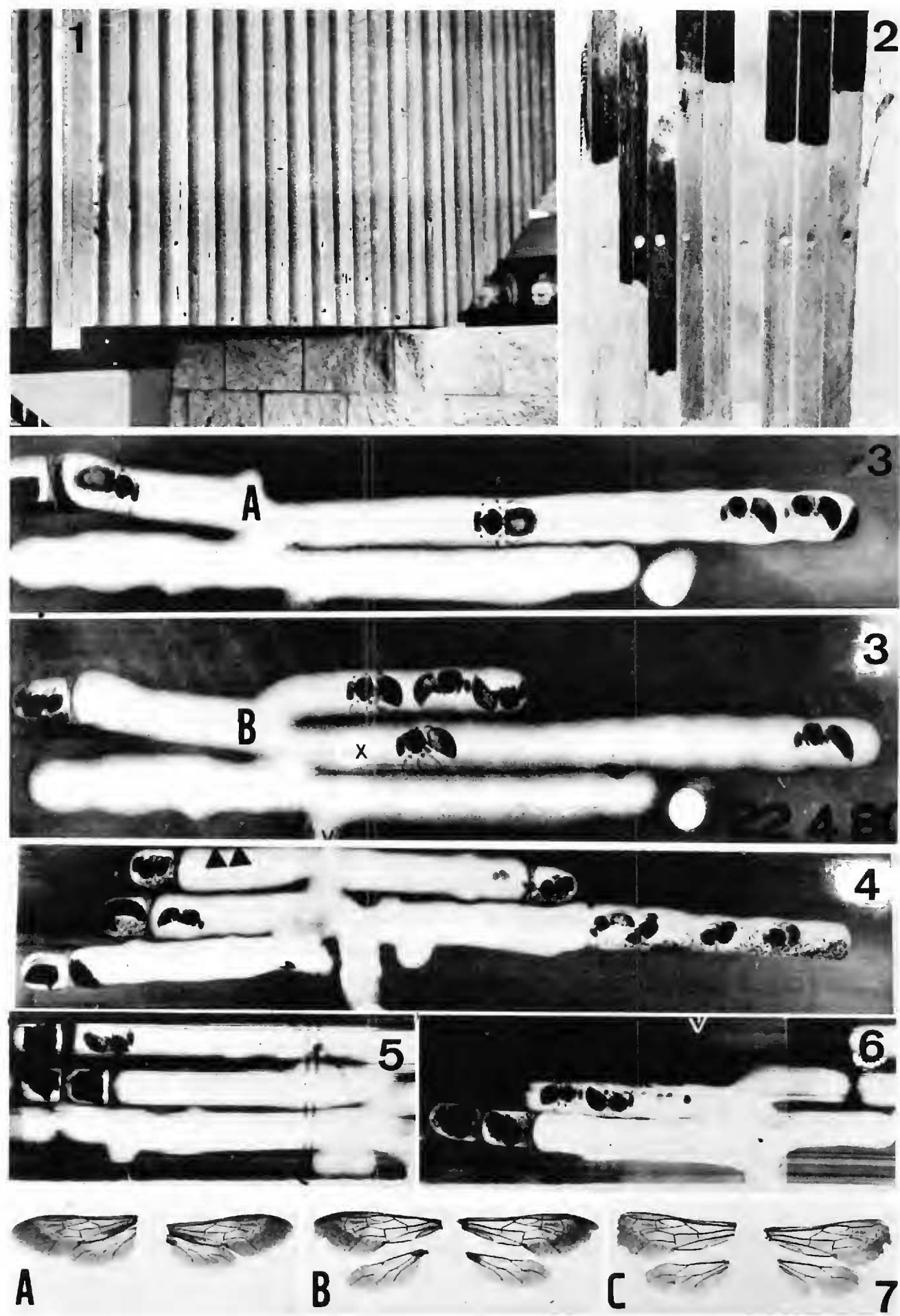
Nesting substrates and nest structure.—Hurd (1978) listed numerous nesting substrates used by this bee. In this study, I found nests in structural timber, mainly introduced redwood timbers (*Sequoia sempervirens* Endl.) that are abundantly used for construction, panelling, decoration and fence building. Nests were found in a variety of shapes and sizes of this wood, provided its thickness exceeded about 2 cm. Dead parts of plants also served as nesting sites. The ones observed in this study, branches of umbrella trees (*Bassaia actinophylla*), *Hibiscus* spp. and baobab (*Adansonia digitata* L.). There were also reports of nests in dead *Agave* flowering stalks, dead branches of *Plumeria* spp. and dead trunks of palm trees.

Nest digging was initiated by the bees even in unsuitable substrates, such as 0.75 cm thick wooden stakes. A number of such cases were recorded during February 1980 on the island of Molokai where the bees dug cavities, and even holes through pine and redwood marking-stakes in pineapple fields (Fig. 2). At times, when the bees encountered wooden stakes that had been piled up, they dug tunnels through a number of them, acting as if they were a solid wooden mass. A similar activity was seen in an old pile of redwood boards in the Waimanolo experiment station on Oahu, where the bees not only dug through 2, overlaying, 1½ thick boards but even nested in this compound.

It has been observed in other carpenter bee species that, although they often dig extensive tunnels, they rarely penetrate the nest walls to the outside. *X. sonora* was the first carpenter bee species in which I observed several cases in which the nest wall was broken often. This usually took the shape of small holes or longitudinal clefts in the wood. Additionally, I found secondary entrance holes to nests, that were obtained through the digging action of the bees from the inside of the nest (Fig. 3). These were especially common when nests have been dug in extensive wooden structures such as the roof of the Molokai airport building, in which probably many generations of bees have already developed.

Although the *X. sonora* female starts her nest with 1 tunnel, the nests usually become more complex and often have 4–5 tunnels each (Table 1 and Figs. 3–6). The number of bees developing simultaneously varied from 1–8, the high numbers including progeny of different ages, usually very young bees as well as pupae. All of the eggs were laid by the same female, however a number of bees often resided in the same nest. Tunnel length varied from 4 to 21.5 cm in the 4 nests studied, but tunnels in other nests were found to reach over 30 cm.

Developmental history and daily activity.—Ovipositions took place the year round. During the winter, from December to March, their frequency seemed to recede with the decline in the bees' activity, and the duration of development took some 10–15 days longer than in the fall. However, pollen



Figs. 1–7. Fig. 1. Decorative redwood sticks at the Fashion Fabrics store in Honolulu, perforated by nest holes of *X. sonorina*. Fig. 2. Holes made by females of *X. sonorina* in marking stakes made out of wood lathe used in the pineapple fields of Molokai. Fig. 3. X-ray radiogram

Table 1. Nesting data for 4 nests of *X. sonora*.

Nest no.	Date	No. of tunnels/nest		No. of progeny		No. of adult bees	Nest tunnel lengths (cm)
		Sum	With progeny	Per nest	Per tunnel (max)		
1	27.X	4	2	2	1	2	10, 10, 13, 20
	26.XI	4	1	3	3	1	
	19.II	4	2	4	3	3	
	10.VI	5	1	1	1	6	9.2
	15.V	5	1	3	3	3	
2	25.IX	5	4	8	5	1	5, 9, 11, 11, 21.5
	16.X	5	5	8	3	2	
	30.X	5	5	7	3	6	
3	20.IX	4	3	4	2	3	4, 7, 10, 14
4	26.X	3	2	4	2	1	18, 19, 20

was collected and eggs were laid. Periodic visits to Waimanalo, on the windward side of the Island indicated that nesting activity was discontinued there, probably due to the much higher rainfall.

Duration of development out of doors from egg to adult was about 41–50 days. The breakdown was as follows: Eggs 2–3; Larva I 3–4; Larva II 3–5; Larva III 3–5; Non feeding larva (prepupa) 9–14; Pupa 21–27 days. The time from beginning of pollen slant deposition to egg laying varied since, like *X. pubescens* (Gerling, Hurd, and Hefetz, 1981) *X. sonora* often removes the pollen slant after its formation. At times when it was not removed, pollen slant build-up that preceded oviposition lasted about 4 days.

Tunnel digging is, apparently, done in increments. A bee was observed digging in a redwood board for 10 consecutive hours, reaching 2–3 cm in depth, and then stopping. We have no record on the continuation of this excavation, but the X-ray records of nest No. 1, to which a 5th tunnel was added (Table 1) showed that in that case, digging took 14 days from start to the final length of 9 cm, and was done in 3 or more increments, with several days' cessation between each.

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of nest No. 1, A—on Jan. 4, and B—on Apr. 22, 1980. V, original; X, secondary entrance holes. Figs. 4–6. X-ray radiograms of nests No. 2–4 respectively. Fig. 7. Wings of A. young, B. active, and C. old *X. sonora* females.

Table 2. Incidence of regurgitation May 15, 1980.

Hour	Temp. in shade °C	No. of guard bees at nest entrances	No. of bees seen regurgitating	% of bees regurgitating
715*	23	?	1	—
840	27	33	8	24.2
1020	29	34	12	35.3
1210	31	31	19	61.3
1525	32.5	34	19	55.9

* 1st bee seen regurgitating.

The emerging females are black but their wings are milky-white. The wings darken within 24–28 hours, the bees attain the ability to buzz during the first week and to fly under laboratory conditions after two or more weeks. Bees that developed in the field appeared to fly earlier.

The emerging adults clean their nest from fecal and nest-shaving debris, but usually do not disturb younger progeny that might be in the same tunnels. They are fed by their mother during the teneral stage, and in the lab. they readily fed on honey from about the 4th day after emergence.

Different phases in the life cycle of carpenter bees from emergence to death can be followed by observing the condition of various body parts and organs that change with time (Daly, 1966; Gerling and Hermann, 1978). Accordingly, it is expected that the wings of bees will be more worn and their ends frayed with increase of field activity (Fig. 7), the yellow gland will be developed in actively nesting bees (Gerling, Orion, and Ovadia, 1979) and the oocytes in the ovarioles will be larger as oviposition time draws near.

Table 3 depicts the conditions of 6 parameters that were examined in 28 bees. Two were overwintering bees, that emerged from their pupae in nest No. 2 between Nov. 15 and 30 and were removed from that nest and dissected on Feb. 25 and 26. Nine of the rest were collected while visiting flowers, in particular *Crotalaria mucronata* Desr. at Waimanalo, and the remaining 17 are from "Fashion Fabrics" and were caught with a net when leaving or approaching their nests. Aside from the two bees that were removed from the nests, all were collected from the middle of March on, i.e., during nesting time.

Two of the 10 unmated bees, one from flowers at Waimanalo and the other from the nests at "Fashion Fabrics," had very worn wings that indicated extensive flight activity. The two bees that were removed from their nests had completely new wings, were unmated, but had a crop that was full of pollen and the ovaries were well developed. Ovarial development was also relatively well advanced (at least one oocyte reaching $\frac{1}{2}$ or more of

Table 3. Results of dissections of *X. sonorina* Feb.–Apr. 1980.

Date	Place	Wing wear	Pollen ¹		Ovary	S ³	Glands ²		Weight (g)
			Stom-ach	Rec-tum			D	Y	
25.II	M	—	+	ND	1/2–2/3	—	—	ND	ND
26.II	M	—	+	ND	1/2–2/3	—	ND	ND	ND
13.III	F.F.	+++	+	+	ND	+	+	—	.668
21.III	F.F.	+	—	—	1/3	—	+	+	ND
21.III	F.F.	+	—	—	2/3	+	+	++	ND
21.III	F.F.	—	+	+	1/2	—	+	++++	ND
23.III	F.F.	++++	+	ND	1/3	+	—	+	ND
24.III	F.F.	—	—	+	1/2	—	+	—	ND
24.III	F.F.	+++	+	+	2/3	+	+	+	ND
28.III	F.F.	+	—	+	1/2	—	+	—	ND
30.III	F.F.	+++	—	+	1/2–2/3	+	+	—	.554
30.III	F.F.	—	—	+	1/4–1/3	—	—	+	.638
30.III	F.F.	++++	—	+	1/2	+	+	+	.690
30.III	F.F.	++++	+	+	2/3	+	+	+	.597
30.III	F.F.	+++	—	+	1/2	+	+	+	ND
30.III	F.F.	++	+	+	1/4	+	—	+	.573
30.III	F.F.	+	+	+	1/2	+	+	+	.677
30.III	F.F.	++++	—	+	1/2–1/3	—	+	+	.535
30.III	F.F.	+	—	+	1/3	+	+	+	.677
8.IV	W	++++	+	ND	1/3	—	+	—	ND
14.IV	W	+++	+	ND	1/2	+	+	++	ND
14.IV	W	++	—	+	1/3	+	+	—	ND
14.IV	W	—	—	+	1/4	—	—	—	ND
14.IV	W	++++	ND	ND	ND	+	+	—	.715
14.IV	W	+++	+	ND	1/3	+	+	ND	ND
14.IV	W	+++	—	+	1/3	+	+	+	ND
14.IV	W	+++	+	ND	ND	+	+	++	ND
15.IV	W	+++	—	+	1/2	+	+	++	ND

M—Manoa; F.F.—Fashion Fabrics; W—Waimanalo; Ovary: expressed as a fraction of maximal size attainable by the oocyte; S—Spermatheca; D—Dufour; Y—Yellow gland; ND—No data. ¹ + = pollen present, ² + = full, ³ + = well developed.

maximal size) in four more unmated bees indicating that mating was not a prerequisite for such an occurrence. The pollen in the crop of the two young bees might have come from one or more of a number of sources, like bee bread or its remnants in the nest, new pollen from a pollen slant prepared by the older bee residing in that nest, or trophallaxis with that female. Most bees had many pollen remnants in their rectum indicating that they not only carried this material in their crop for bee bread preparation (Schremmer, 1972) but also fed on it.

Yellow glands were well developed only in bees that showed ovarial de-

velopment, in one case even in an unmated bee. There were, however, several cases of both mated and unmated bees in which these glands were white and undeveloped.

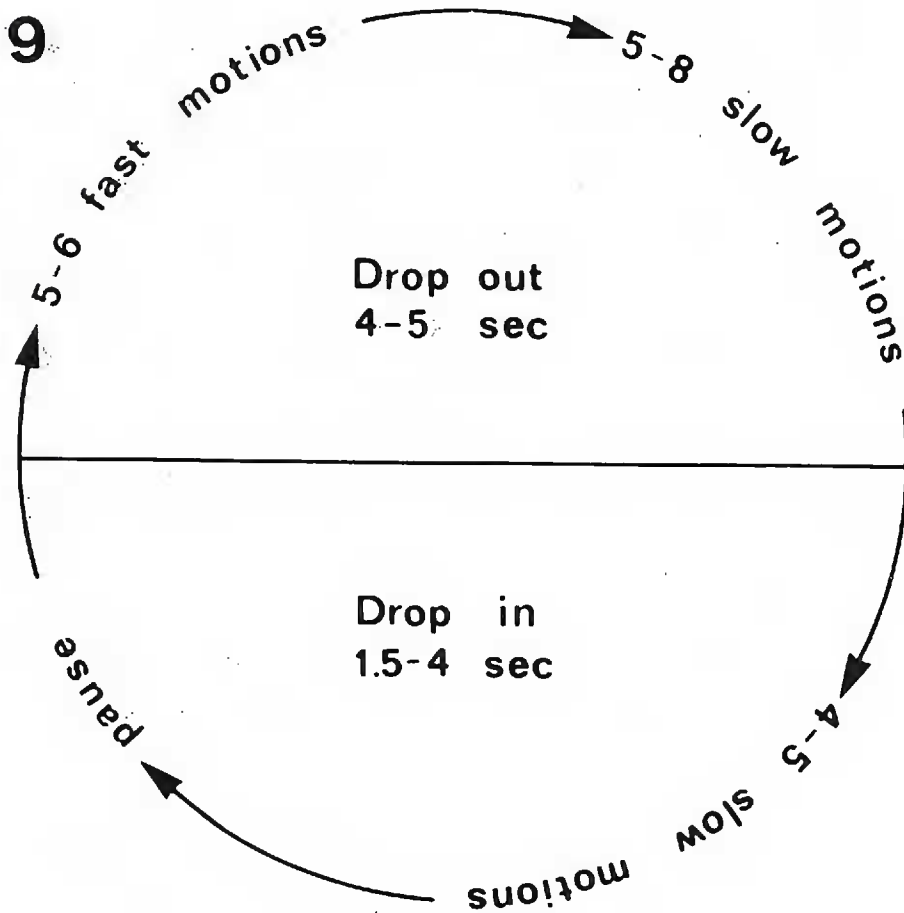
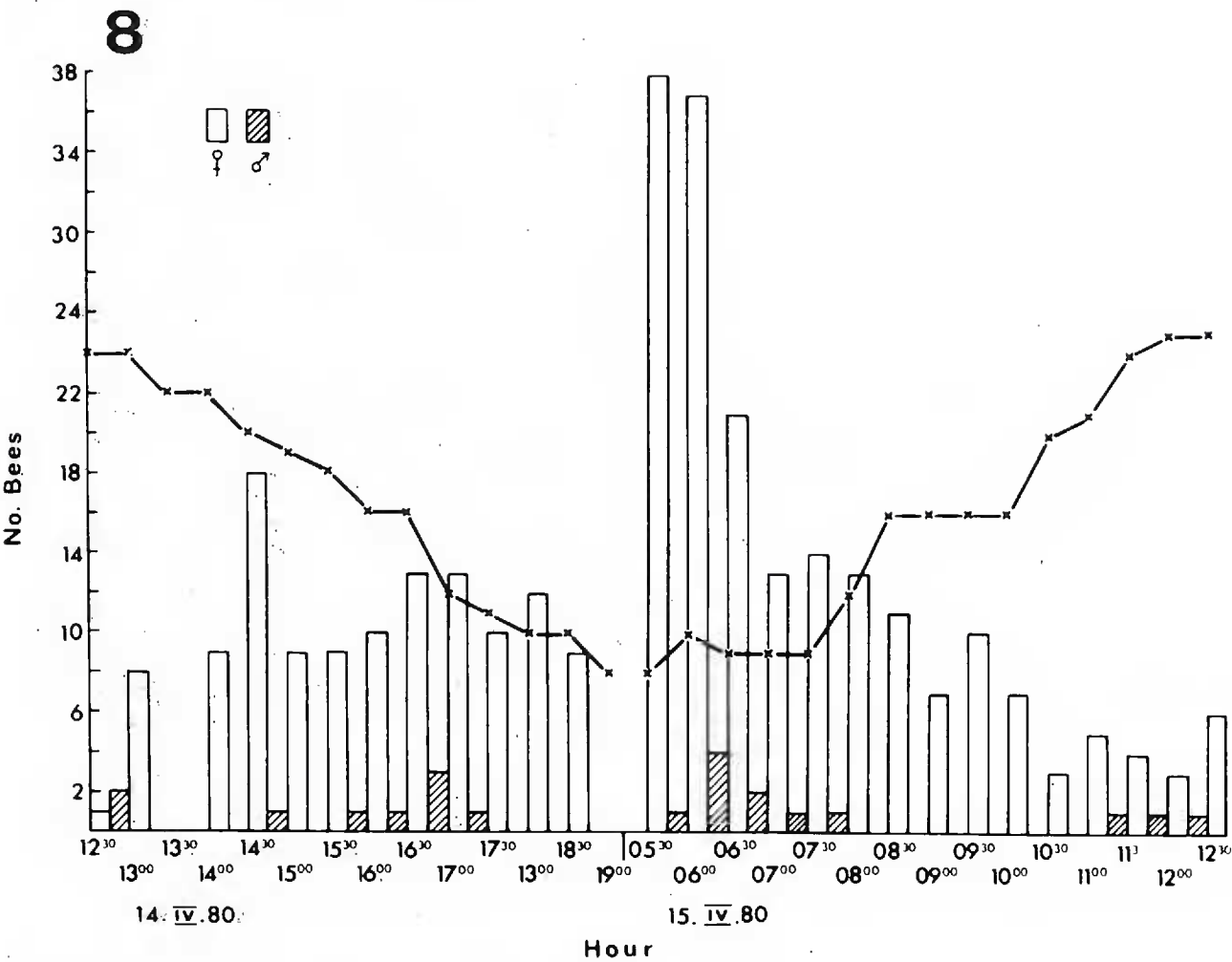
The laboratory material was reared in glass tubes lined with absorbent paper. Following adult emergence these were placed on one tray allowing bees to enter and leave their breeding place. The bees, that first remained inside the tubes, started showing up at the entrance on the 5th post-emergence day and from the 9th day they left their nest occasionally, for varying lengths of time and walked on the tray and in its vicinity. They usually found their way back to the tubes but did not necessarily enter the same tube in which they developed. Thus, marked bees from a number of tubes were found concentrated in one tube, and showed no animosity towards each other. Further confirmation of the lack of specific attraction to the place of emergence was furnished when the locations of the tubes were changed during the absence of the bees, and when the absorbent paper linings of the tubes, that bear many of the odors deposited by the bees during their development, were interchanged. The re-entry of the bees into the tubes after their departure could not be correlated with either tube location or order.

In Manoa, nesting activity diminished during the winter months of December–March, no new diggings were observed, but the bees continued to be active and some new progeny developed. The progeny that had emerged during the fall remained as unmated individuals with their mother through the short winter. Thereafter some females nested in the same tunnel complex as their mothers, whereas others dug themselves new nests. Nest digging was resumed during March and, once started, continued even during stormy weather.

Due to the continuous breeding of *X. sonora* throughout the year, there is an extensive overlap of generations and it is possible to find old mothers side by side with young females, both mated and unmated. It is also possible to find females who dig and start new nests at the same time as others establish a 2nd or 3rd generation in already established nests. From May 14 at 1230 until May 15 at 1230 the activity of the bees at the “Fashion Fabrics” location in Honolulu was followed. For this purpose, all of the bees in the air were counted at that location each ½ hour. The results show (Fig. 8) that most of *X. sonora*, like *X. pubescens* (Ben Mordechai et al., 1978), fly about the break of day (0530–0600 in our case, when the sun started shining in that place at 0615). Moreover, as soon as the boards with the

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Figs. 8, 9. Fig. 8. Activity of *X. sonora* at the Fashion Fabrics location from April 14, 1980 at 1200 to April 15, 1980 at 1200. Fig. 9. Diagram showing the location of the nectar droplet and the maxillary motions performed during nectar regurgitation.



nests become shady, at 1900 the bees stopped flying in spite of the presence of light and sufficiently high temperatures.

Active bees were seen regurgitating nectar at their nest entrance during the warm hours of the day. The incidence of this phenomenon, that has also been observed by Nishida (1963) for *X. sonora* and by Corbet and Willmer (1980) for *X. mordax* Smith, was recorded during May 15. From Table 2 it is evident that, during the limited observation, the total number of nests being guarded at the same time changed only a little, but the number of regurgitating bees, and their percentage of the guards rose with time and temperature increase. The lack of replication to these observations precludes the possibility of deriving quantitative conclusions about this phenomenon, but strengthens the impression that regurgitation is most prevalent at high ambient temperatures. Regurgitation occurs when the bee moves a drop of liquid from her mouth, out among the galeae and then imbibes it again. This is followed by nearly regular opening and closing of the mandibles. The sequence during the regurgitation cycles included fast and slow mandibular movements, during some of which the drop appeared (Fig. 9).

Relationship among the cohabitant females.—The *X. sonora* female may nest solitarily. Moreover, her progeny may reach adulthood, both in the field and in the laboratory, even in the absence of their mother. However, very often the bees nest gregariously, with several females being present continuously in the same nest. They share guard duties and the field-going female feeds the other through trophallaxis. This facultative, gregarious condition is created from the natural growth and development of the progeny within the nest, or from the joining of a number of females to form a group within the same nest. As far as could be observed, only one female, the mother, lays eggs whereas the role of the other bees may be confined to guarding duties as in *X. pubescens* (Gerling, Hurd, and Hefetz, 1981). As said, occasional unmated females were found to have very worn wings. This was considered unusual since the normal amount of nectar collecting done before mating is not large and would not be expected to result in worn wings.

The males left the nest once the teneral stage had elapsed, except during the winter, when they remained in the nest until spring-nesting activities start during March and April. Thereafter they were found in old, abandoned carpenter bee nests in dead *Hibiscus* branches, and in redwood boards. They were seen feeding on nectar of flowers such as *Samanea saman* (Jacq.) and *Bougainvillea* sp. I was unable to find the location of their territorial flights and have but one record of such an occurrence about a *Bougainvillea* hedge near a fence in which *X. sonora* nests existed on the Island of Kauai.

Flower relations.—*Xylocopa* species, especially the tropical ones, are reputed as having a strong tendency to rob nectar (Barrows, 1980; Faegri and van der Pijl, 1979), and *X. sonora* is no exception. The extent of the phenomena and the mechanisms involved have been discussed in the lit-

Table 4. Flower species on which nectar robbery was observed from September 1979 to June 1980.

Family	Flower species	Previously recorded	Abundance of cuts
Acanthaceae	<i>Asystasia gangetica</i> (L.)	Barrows, 1980	+++
	T. Andres		
	<i>Sanchesia nobilis</i> Hook.	—	+++
Apocynaceae	<i>Allamanda oenotherifolia</i> Pohl	Nishida, 1963	+
	<i>Catharantus (Vinca) roseus</i> (L.)	—	++
	<i>Ervatamia divaricata</i> (L.)	—	+
	<i>Thevetia peruviana</i> (Pers.) Schum.	Barrows, 1980	+++
Bignoniaceae	<i>Doxantha unguis-cati</i> (L.)	—	+++
	<i>Tabebuia argenta</i> (Bur. & K.) Schum.	—	+++
	<i>Tabebuia pentaphylla</i> (L.)	—	+++
Caprifoliaceae	<i>Lonicera japonica</i> Thunb.	—	++
Boraginaceae	<i>Cordia subcordata</i> Lam.	—	+
Malvaceae	<i>Hibiscus rosa-sinensis</i> L.	Barrows, 1980	+
	<i>Hibiscus rosa-sinensis</i> × <i>H. schizopetalus</i>	—	+
	<i>Hibiscus schizopetalus</i> Hooker	—	+++
Solanaceae	<i>Brunfelsia americana</i> L.	—	++
Verbenaceae	<i>Stachytarpheta mutabilis</i> (Jacq.)	Barrows, 1980	++

erature (van der Pijl, 1954; Schremmer, 1972; Barrows, 1980). A mechanism that involves the activity of ants, which prevent the bees from robbing flowers that have extra floral nectaries, has also been described and named “ant guard” (van der Pijl, 1954).

The present observations confirmed the knowledge about the flower species robbed by *X. sonora* and added several species to the list (Table 4). Moreover, noticing the behavior of *X. sonora* while visiting flowers, one can expect numerous additional flowers of the Sympetalae to be added to this list as the number of observations grows. Visits made to the flowers of the genus *Hibiscus* proved to be of special interest. Hawaii abounds in *Hibiscus* belonging to numerous varieties, most of which are hybrids or cultivars of *H. rosa sinensis* L. Possibly, the most common hybrid is the cross *H. rosa sinensis* × *H. schizopetalus* Hooker that produced red, pink or white flowers and is reared in large numbers as a hedge plant. The flowers of this variety have a long, slender, and thin walled calyx as in *H. schizopetalus*, the bracts are short, and the petals are somewhat deflexed and a little serrate at the edge. They differ in these characteristics from many cultivars of *H. rosa*

sinensis that have long bracts hugging the calyx that is goblet-shaped and thick walled, and that have smooth edged petals. Both variety groups have the typical nectaries located at the base of the corolla, hidden by the calyx, and both produce nectar, that is then visited by ants.

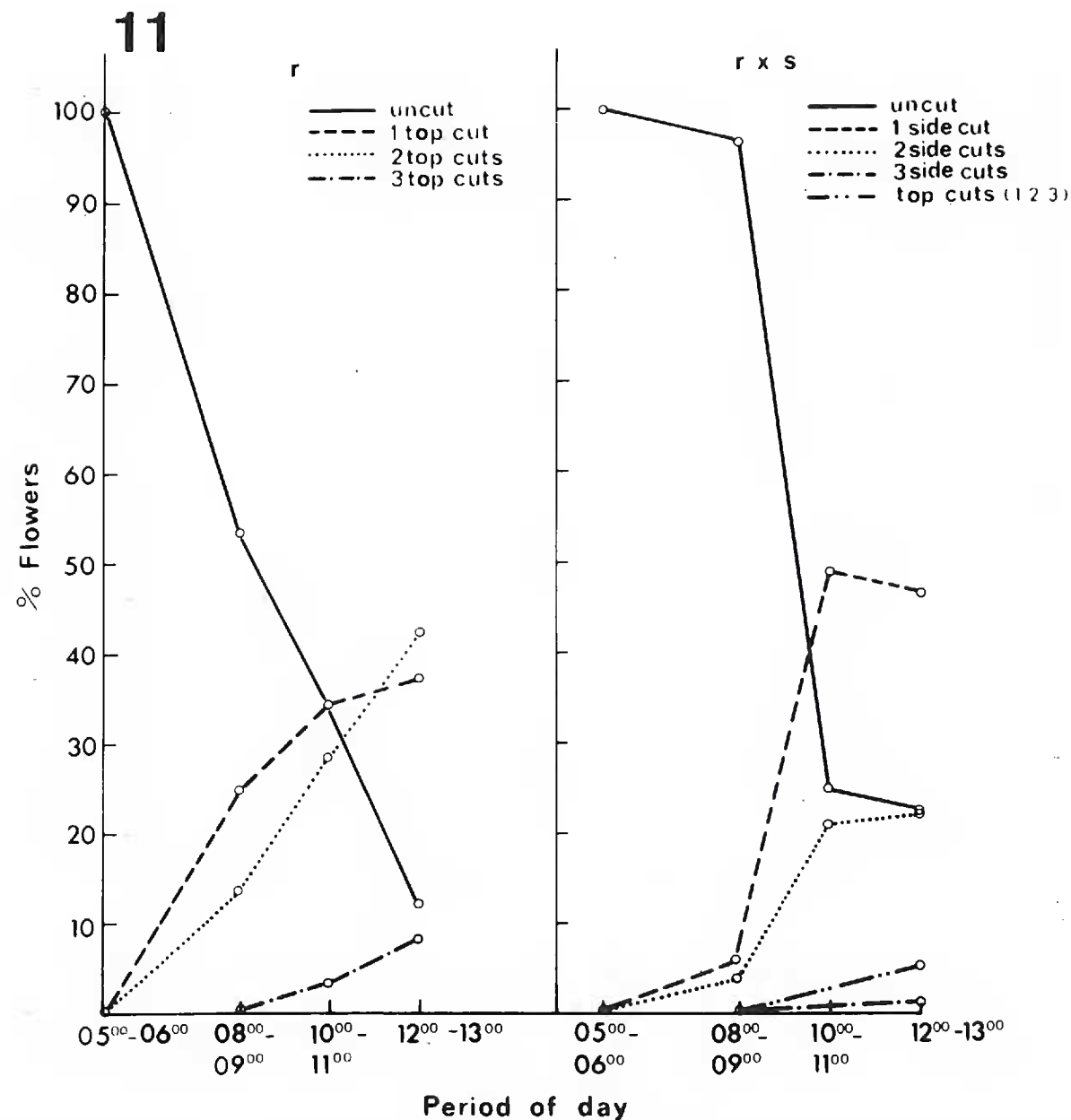
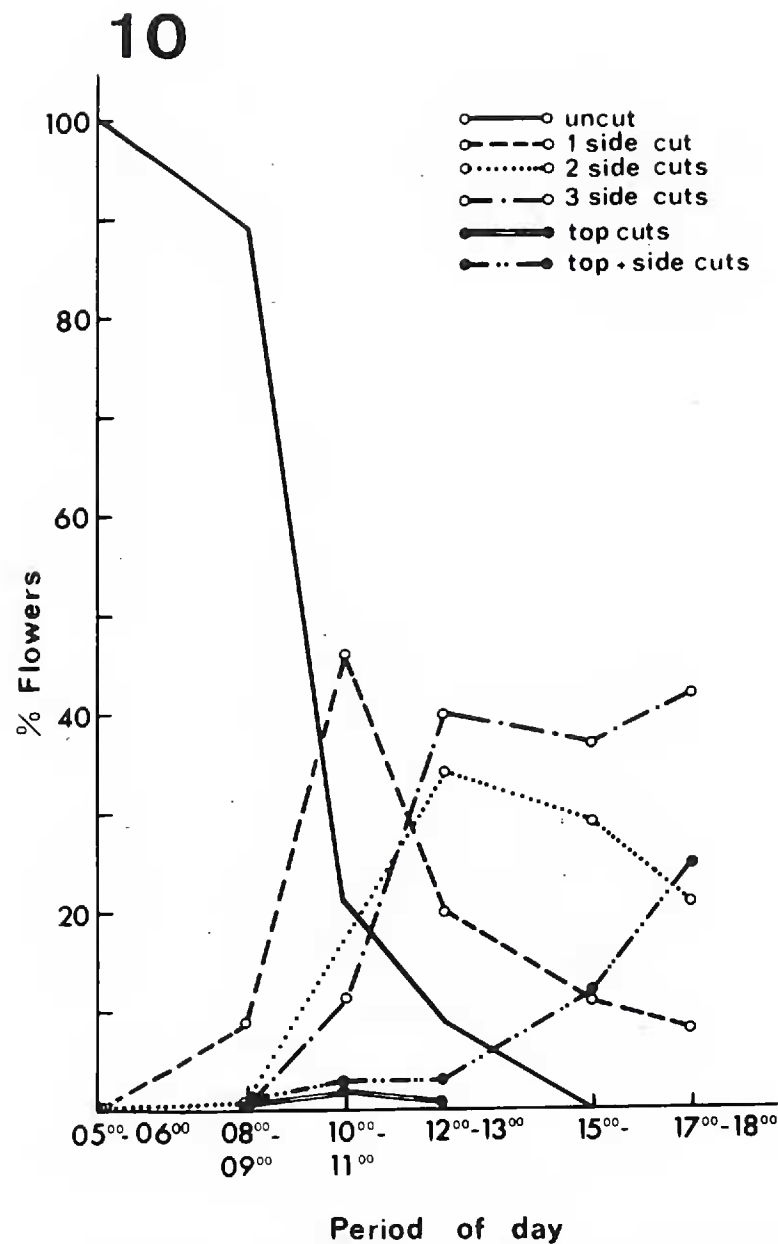
Observations were conducted in order to understand the relationships of the bees to the above mentioned *Hibiscus* species. These were carried out in a number of ways: 1. Watching the behavior of the visiting bees; 2. Following the blooming cycle of marked flowers from the bud to the wilting stage; 3. Sampling flowers and registering their condition as to the presence of nectar, ants, and incisions made by the visiting bees.

The behavior of the bees consisted of approaching the flower, flying near it for a few seconds and either departing, or landing on the petals. In the former cases, ants (*Pheidole megacephala* (F.)) were sometimes, but not always, found in the calyx. In the latter case, the bees always turned with their head to the petals and walked down to the calyx, where they robbed the nectar of the flower. This was done by cutting the calyx either from the top margin down by slitting it along its side or, rarely, by biting it. The mouthparts are inserted in the slit and nectar is imbibed. At times, the bees utilized present slits.

The blooming cycle of *Hibiscus* plants lasts one day. They open in the early morning hours, and close in the afternoon or evening. However, the opening time of the two varieties under observation differed. *H. rosa sinensis* flowers opened at sunrise, whereas the flowers of the crosses with *H. schizopetalus* usually opened later. This was true especially of the white and pink flowered varieties, that opened between 0730 and 0830, and in shady spots even later.

The behavior of the bees and the conditions of the flowers of *H. rosa sinensis* (r), *H. schizopetalus* (s) and the cross (r×s) were noted at various times and in several locations. Following notation that differences existed between flower visits on (r) and (r×s), counts were made of flowers on two hedges, one of (r) and one of (r×s) on the Manoa campus. In January, February and March, the flowers were counted and sorted once a day, late in the afternoon. In April and May several daily counts were made of the same flowers. The results are depicted in Table 2, whereas Figures 10 and 11 show the dynamics of the flower visits. Figure 10 compares the visit from sunrise to 1300 in (r) and (r×s) whereas Figure 11 depicts a whole day's visiting sequence on (r×s).

Although the degree to which (r) was visited varied greatly, it was always less than that of (r×s), cuts in calyces of which occurred usually on 100% of the flowers (Table 5). Visits to (r) began early in the morning and by 0800 bees have visited already over half of the flowers that were going to be visited on that day. Most visits to (r×s) started, in nice weather, about 0800, when



Figs. 10, 11. Fig. 10. Percent flower-calyx incisions made by *X. sonorina* during May 2, 1980 on 100 flowers of the hybrid *H. rosa sinensis* × *H. schizopetalus* on the Manoa campus. Fig. 11. Percent flower-calyx incisions made by *X. sonorina* during April 15, 1980 on 100 flowers of 2 hibiscus varieties (*H. rosa sinensis* = r and *H. rosa sinensis* × *H. schizopetalus* = r × s) on the Manoa campus.

Table 5. Afternoon counts of total flower numbers visited on hedges of *H. rosa sinensis* (r) and *H. rosa sinensis* × *schizopetalus* (r×s). The two records of May 5 on *H. rosa sinensis* were taken from the same hedge.

Variety	Place	Date	Uncut flowers		Top cut		Side cut		Top and side cut		n
			No.	%	No.	%	No.	%	No.	%	
r×s	Hawaii Kai	27.I	0	0	0	0	8	32	17	68	25
	Manoa	29.I	0	0	0	0	15	37.5	25	62.5	40
	Manoa	12.II	0	0	2	16.6	4	33.3	7	5.3	13
	Manoa	10.III	0	0	?	?	?	?	?	?	100+
	Manoa	11.III	1	0.6	?	?	?	?	?	?	150
	Manoa	2.V	0	0	0	0	75	75	25	25	100
r	Hawaii Kai	27.I	30	60	18	36	2	4	0	0	50
	Manoa	29.I	20	50	20	50	0	0	0	0	40
	Manoa	12.III	12	80	3	20	0	0	0	0	40
	Manoa	10.III	6	8.5	61	87.1	0	0	3	4.2	70
	Manoa	11.III	16	26	43	71	1	1.6	0	0	60
	Manoa	2.V	24	24	76	76	0	0	0	0	100
	Manoa	2.V	79	79	19	19	0	0	1	1	100

the flowers opened and later under cloudy and rainy weather. Once started, the bees visited most of the flowers within two hours (Fig. 10).

More than one cut per flower was made in (r×s) and, to a lesser degree, in (r). Multiple cuts started to show up when uncut flowers were still available (Figs. 10, 11), at the same time bees were seen feeding through cuts made by others, an activity that occasionally caused an enlargement of the slit in the calyx.

Definite preference existed to “top cuts” from the margin of the calyx down, in (r) and to side slits in (r×s). Top cuts appear in (r×s) mainly after side slits have been made in all of the flowers. These are sometimes enlarged through the pushing of the bees’ head, and may join a side slit to make a substantial tear in the calyx.

Van der Pijl’s (1954) observation that ants visiting the nectaries preclude robbery by bees prompted an examination of the subject in the case of *Hibiscus* and *X. sonorina*. In the evening of January 27, 25 flowers of (r×s) and 50 flowers of (r) were examined for both visits by bees as evidenced by cuts and slits in the calyces, and the presence of ants. All of the calyces of (r×s) and 20 calyces of (r) showed visits by bees (Table 5), two of the former and 17 of the latter had also ants in them. In addition, 15 (r) flowers that have not been cut by bees had ants in them. The possibility that the ants have reached the flowers after the bees have finished visiting them was examined by direct observation and was found to be incorrect.

Additional observations of behavior of *Hibiscus*-visiting bees revealed that bees may approach flowers, hover above them and at times land on them, and leave without robbing nectar. In all cases examination of these flowers showed that ants of the species *P. megacephala* were inside. No such behavior was observed when other ant species, especially *Tetramorium similis* (Fr. Smith) were in the flower. Moreover, only a few of the flower-visiting ants found in the count taken on January 27 belonged to *P. megacephala*.

Discussion

In general, the biology and ecology of *X. sonora* conforms with that of other *Xylocopa* species. Some points in its biology may be noteworthy either because they are different than those of other species studied, or because they may shed some light upon the social relationships of the bees. *X. sonora* starts to develop a nest as a single female, and later may be joined by additional females. The latter may be her progeny, or other bees that have come to reside with her. This phenomenon has also been observed with *X. pubescens* (Ben Mordechai et al., 1978). Similarly, each nesting *X. virginica* (L.) female is often joined by a non nesting female who remains with her for the duration of the nesting period. However, in the latter case, we do not know if there is familial relationship between the two bees (Gerling and Hermann, 1978). Yet, in all known cases, only one female did the work of collecting, cell preparing, and ovipositing; whereas the other bees performed mainly guard, and nest cleaning duties.

Hierarchy of the bees within the nest, as studied in some *Xylocopa* species (Bonelli, 1976; Gerling, Hurd, and Hefetz, 1981) is such that the mother does all the outside work whereas one daughter usually guards the entrance and the others stay inside until they are ready to leave, mate, and establish their own nest. The latter is often near, or a continuation of, the mother's nest.

The finding of females that were unfertilized but had worn wings indicates that they did more than their normal share of outdoor activity. It is possible that they were active for an unusually long time out of doors, perhaps until providing food for other nest inhabitants. This extended period of activity while being unmated may have resulted from inability to find mates due to seasonal or topographical problems. It also might have been the consequence of pheromonal suppression of the mating capacity of these bees by others, possibly their sisters. The possibility of such pheromonal disruption of activity may be indicated by the fact that mating activity in some carpenter bee species was shown to be regulated by pheromones (Velthuis and Gerling, 1980).

The floral relationships of *X. sonora* differ from those of several other studied species. Van der Pijl (1954) recorded the frequent visits of *Xylocopa*

species on *Calotropis gigantea* R. Br. Likewise strong association between *X. pubescens* and *X. sulcatipes* Maa and *C. procera* (Ait.) Ait. f. exists (Gerling, personal observations). Yet *X. sonorina* was never seen visiting the abundant *C. gigantea* growing on Oahu, even when it was flowering near the bees' nests. Such an association was also never mentioned by Nishida (1963) in his discussion of pollination and flower visits by *X. sonorina*.

The range of plant species that are robbed is also interesting, since several of these occur as introduced plants, both in Hawaii and in Israel. Indeed, some of the plant species, most notoriously *Lonicera japonica* Thunb., are robbed in both countries. However, neither *Hibiscus* species, nor *Thevetia peruviana* were found to be robbed in Israel in spite of their abundance in the ranges of several *Xylocopa* species.

When the range of plant species that are robbed is compared with the bees' natural distribution, it becomes apparent that *X. pubescens* robs mainly (or perhaps only) plants that originate in that range (e.g., *Lonicera italica* is wild in Israel, and *Clerodendron inerme* Gaertn. is from India). *X. sonorina*, on the other hand, robs both *Thevetia peruviana* that is a New World species, and *Hibiscus* that is of Asiatic origin.

Apparently, an element of experimenting and learning exists in the adoption of the new flower species and robbing them of their nectar, and *X. sonorina* has been able to expand her flower range much more than *X. pubescens* in that respect.

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Footnote

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